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ROBUST MANGROVE CHANNEL ASSESSMENT FOR MANGROVE CHANNEL VULNERABILITY VALUATION: A CONCEPT

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Abstract:

Despite being a highly beneficial marine ecosystem that offers unique habitats and biodiversity opportunities, mangrove areas have significantly degraded in recent decades due to unsustainable use, particularly along creeks and channels. This degradation will eventually have an impact on the services provided by mangrove forests, with factors such as sea level rise and human activities being found to be contributing factors. Changes in channel morphology caused by these factors also lead to the loss of mangrove trees in bank areas. While such changes occur naturally over long periods, the increasing prevalence of ecotourism activities is accelerating their effects. Even though some valuations with complex assessment have been developed but, those complexity are not viable to be carried out easily by community and the assessment through the mangrove channel have not yet been well addressed. Thus, this paper proposed a feasible assessment focusing on mangrove channel that is robust and practical for implementation. The two main objectives of this study are to thoroughly investigate relevant parameters and to examine appropriately the parameters rank for mangrove channel

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vulnerability assessment. The proposed assessment should include six important parameters which signifies their importance to the mangrove channel environment. All parameters studied will be rank from one to five (lowest to highest) to indicates their contribution to the mangrove channel vulnerability. The total average scores of the parameters will determine the vulnerability status of a particular mangrove channel. Keeping track of the state of mangrove channels is crucial for achieving sustainable development, even in situations where climate factors are beyond our control. The proposed concept should be evaluated and perhaps it will be useful in the exploration of mangrove and brings mutual benefits between the community and the environment.

Keywords:

Mangrove Channel, Mangrove Vulnerability, Channel morphology, Sea Level Rise

Introduction

Mangroves are amongst the most productive marine ecosystems on Earth, providing a unique habitat opportunity and biodiversity. The mangrove forest is an ecosystem that may be found along the coastal area, tidal mudflats and channel with seawater that flows inland through the streams, brackish water along the river. Mangrove plays essential roles towards the ecosystem including as i) natural barrier, ii) nursery ground, iii) reduces coastal erosion, iv) shoreline stabilization, v) nutrient and sediment retention, vi) storm protection, vii) flood and river management, viii) water quality and they act as ix) frontiers that protect the coastal land against the destruction of ocean waves, tsunamis, and storms (Ellison, 2015; Cabral et al., 2017; Yunus et al., 2018; Mohd et al., 2019; Saha et al., 2019; Goldberg et al., 2020; Kanniah et al., 2021). Aside from one of the most productive forest ecosystems, mangrove forests also ideal areas for monitoring biological response to global climate change, seasonal changes, and disturbances (Zhang et al., 2016).

Recent studies found that mangroves are disappearing at a global scale loss rate of 1–2% per year, and the loss rate was extreme at 35% during the last 20 years (Carugati et al., 2018). While Indo-Pacific region seems to be an area rich in mangrove forest, their mangrove areas also in threat and one significant reason is the sea level rise (SLR). A study by Lovelock et al. (2015) in the Indo-Pacific region has estimated that those selected study sites with low tidal range and low sediment supply could be submerged as early as 2070. The issue is worrying because almost 70% of the study sites selected were in the dangerous region where the current rate of SLR has exceeded the soil surface elevation gain (Lovelock et al., 2015).

Not just climate changes (SLR and altered rainfalls), various human activities and commodities (urban development, aquaculture, and overexploitation of timber, fish, crustaceans, and shellfish) also represent major threats to the mangrove areas (Saha et al., 2019; Kh’ng et al., 2021). Mangrove habitats which are home to wide range of species; now degrading at an alarming rate, due to the direct impact of human activities and global change. However, globally, it was suggested has decreased since 2000 as the emergence of natural drivers that squeezing both of available viable mangrove forest and the effective conservation initiatives (Goldberg et al., 2020) but, the suggestion does not suit the Malaysian scenario, especially at the northern region. In order to keep track and monitor sustainably the mangrove area status, cooperation between community, researcher and agencies hand in hand is vital. Thus, this paper

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objectively aims to develop a robust assessment for the mangrove channel which is feasible to all party.

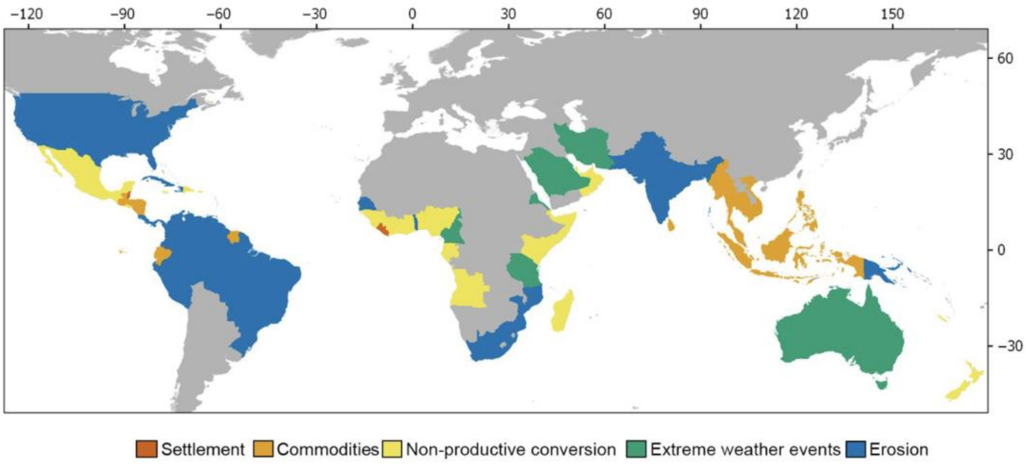

Figure 1: Mangrove Loss Driven Factors Across The Globe From Natural Environment And Man-Made Impact.

Source: Goldberg et. al., 2020

Overall, mangroves are witnessing degradation in many ways such as unsustainable development, deforestation, overfishing, and climate impacts such as SLRs (Suhaimi et al., 2018; Jennerjahn et al., 2017). Deforestation was mainly the issue in early development, where for example the aquaculture site, industries, and tourism (Figure 1). The development would often lead to unsustainable impacts that destructing the nearest area with pollution, sequestration of carbon dioxide, expansion, erosion, and others (Yunus et al., 2018; Karim et al., 2019; Omar et al., 2019). Specifically, Langkawi was too not exempted to this threat. Mangrove exploration also caused disruption to the biological diversity of inactive or migrating species (Azimah & Tarmiji, 2018), changing nature and destroy the potential habitat of resources (Ellison, 2015; Cabral et al., 2017). Due to the exploitations, it has been a threat to Malaysia natural heritage as Langkawi was awarded UNESCO Global Geopark status since 2007 (Khairul et al., 2019; Karim et al., 2019; Mohamad et al., 2020).

Figure 2: Mangrove Loss At Langkawi, Malaysia That Need Attention For Conservation.

Source: Live event on site

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Literature Review

Mangrove Degradation in Malaysia

In Malaysia, the overall mangrove distribution was recorded only 18% at the peninsular region while majorly from Sabah (60%) and Sarawak (22%) (Figure 3). However, studies using satellite images have reported about 2% loss of mangroves for various reasons since 1990 (Omar et al., 2018). Mangrove's study in Malaysia have been started since the 90s, and in 2008 an initiative to manage the mangroves area was published and a year later mangrove rehabilitation was carried out in Selangor. Later on, Perak state followed the good step and includes the nearest community for its managements plan (Abdullah et al., 2014). The effort continued, Mangrove Status in Peninsular Malaysia was published outlining the threats and various recommendations for conservation measures. Up to the latest in the year of 2020, the Status of Mangrove in Malaysia was updated (Hamdan et al., 2020). While the effort is ongoing, further studies throughout Malaysian regions are needed to increase awareness and help to reduce sharp mangrove declination (Abd Rahman & Asmawi, 2016; Musa et al., 2020; Kanniah et al., 2021; Kh’ng et al., 2021).

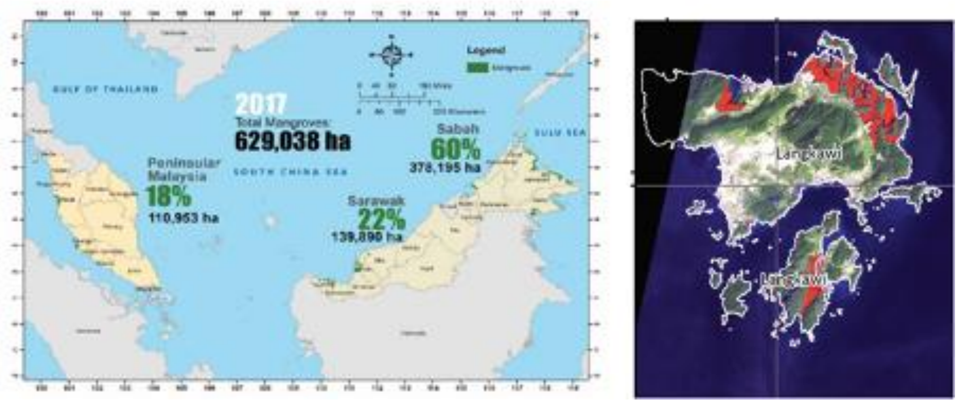

Figure 3: Mangrove Coverage In Malaysia And Langkawi, Kedah

Source: Omar et. al., 2019

Focusing on ecotourism sector at the northern region, Langkawi is a one significant place that attracts tourists from all over the world to its special geological and mangrove areas (Asri & Musa, 2021) which makes it as one prominent site case study. Out of all the peninsular mangrove areas only about 3% located at Pulau Langkawi (Figure 3) which comprising three large mangrove areas, namely 1) Kampong Kuala Isap-Gua Cerita mangroves, 2) Sungai Ayer Hangat-Kubang Badak mangroves, and the 3) Pulau Dayang Bunting-Pulau Tuba mangroves. Besides the ecological attractions, Langkawi also possess diverse species of mangroves with 38 true mangrove species (Omar et al., 2019). It is well known that Langkawi is one of the most visited islands in Malaysia. Over 3 million total tourists recorded in 2019, which is 36 times more than its residents. Regardless covid-19 pandemic, one sector that is thriving for the source of income is eco-tourism (Figure 4). Exploration and exploitation that leveraging nature are unavoidable as Langkawi grows along with people and ecotourism as a prominent source of income (Fauzi et al., 2017). Sustainable development should be implemented where it involves concern for nature and the environment as well as not neglecting all stakeholders who may gain some advantages for them (Hanafiah et al., 2016).

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Figure 4: Eco-Tourism Such As Mangrove Tour Which Tourists Enjoy The Nature Of Langkawi And Conservation Activities To Maintain Fishery Resource.

Source: Live event on site

Figure 5: Mangrove Degradation From Various Activities Over The Years In Langkawi.

Source: Live event on site

Some studies have found that about 2% of mangrove in Langkawi loss severely and continuously from its channel areas since 2007. The degradation of mangrove areas mainly from the human activities was grievous than the climatic effects. The exploitation of the channel that being used as a boat route especially with high travel frequencies will interfere the natural behaviour of the channel and lead to changes in the channel morphology (Figure 5). This adverse effect of rapid widening channel structures will eventually be impacting the mangrove areas and would pose a threat to the Langkawi competency for UNESCO Geopark status. Some conservation activities also being carried out as a positive response towards the issue, however, does the actions really conserving the area or would lead to another impact needs to be further studied. As agencies responsible, NAHRIM and JUPEM have predicted the impact of SLR in Langkawi from 2010 (Figure 6) which could be one of the reasons for mangrove channels widening phenomenon.

The prediction made was often at a large scale using only Teluk Ewa tidal readings. It also focuses more on beach coastal areas where settlement and development are intense. By the year 2020, the increase is only 0.07 meters and considered relatively small. The forecasts then estimating an increase from 0.10 meters to 0.51 meters from 2030 to 2100, and about 13 areas in Langkawi are expected to experience the effects of this SLR (Figure 6). This increase will cause a situation called as mangrove squeeze, where the mangrove will retreat landward as saltwater from SLR gaining territories but for them to shift mangrove territory to the land there is no viable area as development also expanded (Suhaimi et al., 2018).

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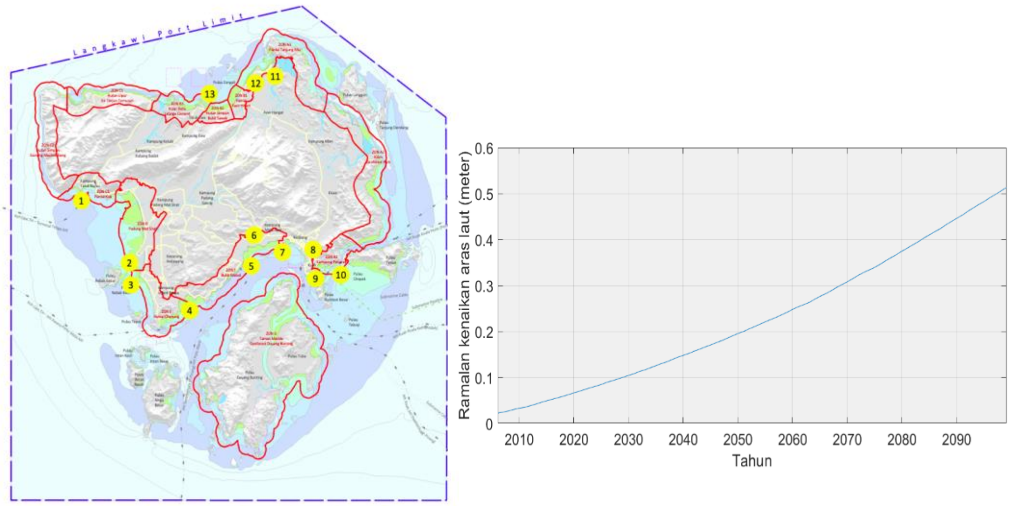

Figure 6: Sea Level Rise (SLR) Prediction at Pulau Langkawi with the Marked (Yellow) Affected Area In 2100.

Source: NAHRIM, 2017

Mangrove Channel

Mangrove channel is an area where seawater flows inland through the streams, brackish water, and the headwater of the river (Saha et al., 2019). Through their channels, naturally, mangroves undergo sediment movement (deposition and erosion) and require a long period of time for change (morphological changes). The channel responds to changes in SLR and sediment movement by modifying their cross-sectional geometry (Channel widening). In these few decades, the disturbance in sediment movement made imbalance with additional tensor from human activities cascading the impact, which led to severe erosion and mangrove loss (Priego-Hernández & Rivera-Trejo, 2016; Yunus et al., 2018, Mohd et al., 2019). Understanding and predicting these morphological changes is important because channel widening can degrade valuable mangrove areas which can also modify the hydrological and ecological function of the mangrove channel (Mariotti, 2018). Studies found that, mangroves twill rap sediment at rising tides, especially during river floods. Thus, a change in the channel hydrology (their current) will affect the sedimentation rate in mangroves channel and their ability which become a challenge for them to keep up with SLR (Jennerjah et al., 2017).

Considering that, the sediment movement in mangrove channels are also complex as their exposed to the tidal dispersion, velocity asymmetry transport, current and waves. However, an increase in sediment supply does not directly increase the deposition within the channel, instead, it can only modify the channel cross section by raising the bottom surface and thus reducing the tidal prism (Jennerjahn et al., 2017; Mariotti, 2018; Goldberg et al., 2020). These factors cause changes not only in channel width, but in depth as well. Therefore, in measuring the cross-sectional geometry of the channel in the mangrove area the calculation of the width to depth ratio should be taken into account.

In Langkawi, the exploitation of channel usage has led to riverbank erosion. A study has predicted the widening using an erosion model and estimated hot spots with line shifts in the Kilim River area (Mohamad et al., 2020). As the erosion worsen and SLR take place, saltwater intrusion within the channel also imposed effects. Another study of saltwater intrusion has found few driven parameters in determining salt intrusion such as tides, channel discharge, and

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channel geometry. Salinity distribution is one of the physical indices that is important to determine water resources management and quality in estuaries. As the saltwater is gaining territories, it will cause mangrove area to squeeze, where they will shift and retreat landward as but there is no possible land for shifting (Suhaimi et al., 2018). Besides SLR impact that we face globally, monsoon is a season the Langkawi faced locally.

The monsoon season in Langkawi is one of the factors that contribute to the number of tourists visits from around the world according to their preferences. Not just that, monsoon also plays their role in environment geomorphology. Additionally, to a certain meteorological condition, the wind and rainfall effect will be obviously impacting Langkawi archipelagos and its mangrove channel areas. Langkawi experiencing four seasons of monsoon, two monsoon seasons: Northeast-monsoon (Nov-Mar) and Southwest-monsoon (May-Sept), and two inter-monsoons (Apr and Oct). The impact of these seasons needs to be considered in assessing mangrove areas, because of the lack of attention given to them elsewhere (Marryanna et al., 2017).

Related to the extent of human impacts on the development of eco-tourism in the channel area, various facilities have been provisioned for this reason. The important role of water transportation, ecotourism, and the fishing industry throughout Langkawi has led to increased numbers of jetties being constructed in mangrove areas. Mangroves are permanently lost at jetty locations. The increase in boat numbers caused increased frequency and intensity of wake currents that erode the banks and degrade mangroves areas.

Thus, a hypothesis to be establishes in order to assess the mangrove channel vulnerability is related to SLR and human activities which are directly interrelated to disturb the natural state of channel morphology that can significantly affect the mangrove degradation. The channel morphology is referring to the cross-sectional geometry of a channel that is subject to change in its width, length, and structures.

Mangrove Vulnerability Assessments

The threat to the mangrove area however could be visualized and measured by the approach of vulnerability assessment. The vulnerability has been conceptualized to have three dimensions that should be categorized into components, or the abstract features upon which to evaluate i) exposure, ii) sensitivity, and iii) adaptive capacity. Exposure refers to extrinsic stresses such as the magnitude and rate of change that a species or system is likely to experience. Where, sensitivity refers to innate characteristics of a species or system and considers the degree to which the system is affected by exposure. These features can each be evaluated using several measurements, which are the observable parameters of each of the component features (Ellison, 2015).

The sensitivity (SI), exposure (EI), and adaptive capacity (ACI) sub-indexes were integrated for the calculation of net vulnerable index (VInet):

$$VInet=(SI+EI)-ACI \tag{1}$$

In order to obtain an overall weighted mangrove vulnerability index (VI), the total of component rank scores (CRscores) should be averaged to the number of total parameters completed (N).

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$$VI=CRscores / N \tag{2}$$

There are various parameters and parameter categories being developed and tested across many regions and some that caught the attention were listed in Table 1. As for example, Omo-Irabor et al. (2011) has used 11 parameters to assess mangrove vulnerability with environmental and socioeconomic factors (two categories). Where, the environmental category includes seven parameters (SLR, temperature, carbon dioxide, precipitation, humidity, pollutants, and invasive species), while the other four were from socioeconomic category (population pressure, deforestation, poverty, and civil conflicts). The parameters were used to model the Western Niger Delta using Spatial Multi-Criteria Analysis from satellite images. Deriving from others, Ellison (2015) had focused on climate change and SLR has suggested that the vulnerability assessment of mangroves by the approaches of multidisciplinary ranking system dedicated the analysis through exposures, sensitivities and adaptive capacities within the study area.

The approaches of this ranking system for vulnerability assessment of mangrove systems are multidisciplinary, integrating biotic and abiotic factors along with human management components (13 components). It also includes accurate and validated methods that have previously been developed to evaluates the health of mangrove forests, coral reefs, and seagrass as well as spatial analysis of coastal changes, topographic survey, and palaeoecological reconstruction of past sea levels. The assessments were carried out at the coastal area of Pacific Island Cameroon, Tanzania, and Fiji.

Adapting from previous research, Yunus et. al. (2018) has assessed their study area and ranked the Mangrove Vulnerability Index (MVI) using up to 14 parameters. Those parameters have been divided into 3 main categories of MVI which are: Physical Mangrove Index (PMI), Biological Mangrove Index (BMI), and Hazard Mangrove Index (HMI), and the assessment was carried out by implementing formula of:

$$MVI=(PMI+BMI+HMI)\ \ / 3 \tag{3}$$

Within the same year, a study at the east coast of Semarang city mangrove habitat assessment was performed blending with the Coastal Vulnerability Index (CVI), where it focused on tidal, salinity, substrate type, and coastline change. However, the study had used the simpler scoring system of 3 scales (low, medium, and high) instead of commonly ranged from 1 to 5, to evaluate the vulnerability (Ahmad & Fuad, 2018). The coastal vulnerabilities calculation did sometimes use mangrove as their suggestion in impact (Mohd et al., 2019) or in others was to determine the vulnerability of the mangrove area itself (Cabral et al., 2017). The flexibility of the formula with the inclusion of variables (A) with a variety of numbers (n), made it versatile to implemented from Gornitz et al. in 1991 (Charrua et al., 2020):

$$CVI = sqrt\ (1/n)\ (A1+ A2+ ...An) \tag{4}$$

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Table 1: The Division Of Categories And Parameters Used From Four Previous Study To Evaluate The Status For Mangrove Area.

Author	Category (No. of parameters)	Parameter	Location
Omo-irabor et. al., (2011)	Environmental (7)	SLR, temperature, CO_2, precipitation, humidity, pollutants, and invasive species	Western Niger Delta, Nigeria
	Socioeconomic (4)	population pressure, deforestation, poverty, and civil conflicts	
Ellison (2015)	Exposure (4)	Tidal range, Sediment supply, Climate change, Relative Sea level rise	Coastal area on Pacific Islands; Cameroon, Fiji & Tanzania
	Sensitivity (5)	Forest health, Mangrove areas, Elevation, Net sedimentation, Adjacent ecosystem health	
	Adaptive Capacity (4)	Management, Stakeholder involvement, Protection status, Migration areas	
Yunus et. al., (2018)	Physical (3)	Mangrove root, Growth-Age-DBH, Height	Pulau Kukup & Sungai Pulai, Malaysia
	Biological (5)	Distance, Soil, Tidal range, Salinity, Mangrove Canopy Density	
	Hazard (4)	Wind, Erosion/Accretion/Abrasion, Sea level change, Human activity	
Faridah-Hanum et. al., (2019)	Mangrove Biotic Integrity (5)	Tree height, Basal area, Tree volume, Aboveground biomass, Crab abundance	Matang Mangrove, Malaysia
	Mangrove Soil (6)	C, N, P, K, Ca, Mg	
	Marine-Mangrove (10)	No of species and it's abundance for;	

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	Phytoplankton, Diatom, Dinoflagellates, Copepods & Jellyfish
Mangrove Hydrology (7)	EC, DO, pH, Turbidity, TSS, Temperature, TDS
Mangrove Socioeconomic (6)	Fish landing, Time spent, Fishing effort, Income, Age, Education

Related to mangrove vulnerability, recently, a comprehensive integration of five categories from ecological socio-economic perspectives for Mangrove Quality Index (MQI) were outlined (Faridah-Hanum et al., 2019). It has explored all key biological, hydrological, ecological, and socio-economic with a total of 43 parameters mentioned adapted from Malaysia Environmental Quality Index in 2010 (https://epi.yale.edu), however 34 parameters were outlined and analysed in the report. Two types of indices were successfully developed to indicate the health status: 1) Mangrove quality index for a specific category (MQI_{Si}) and, 2) Overall MQI to reflect the overall health status of the ecosystem.

Methodology

The Mangrove Channel Vulnerability Assessment Concept

The robust assessment suggested have consider the ability of access and costs that will be involved to analyse the main propositioned parameters based on previous studies. Whether with the help of experts or not, the community itself perhaps should be able to achieve an understanding of their area's vulnerability status with the approach suggested. The parameter advised were shortlisted to six where each of it carries a weight related to mangrove channel represent as appropriate indicator within that region. A simple analysis towards the parameter includes i) channel width ratio, ii) mangrove coverage and species, iii) sea level and tidal, iv) bioturbation, v) boating and vi) stakeholders' involvement. The concept proposed is portray in the Vulnerability Scoping Diagram (VSD) with three-dimensional factors to be assessed (Figure 7).

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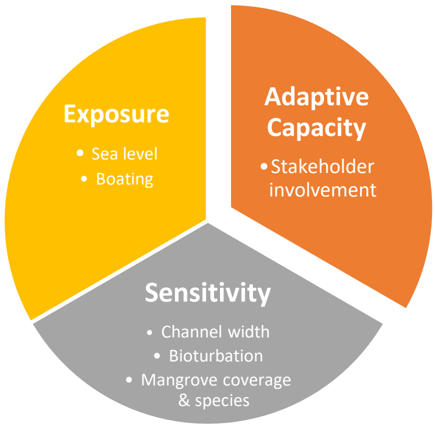

Figure 7: The Three-Dimensional Factors Model With Shortlisted Components For Mangrove Channel Vulnerability Robust Assessment Which Analysed And Adapted From Previous Works And Recent Activities Within The Study Area.

Channel Width

The channel width ratio is an analysis that could be carried out either in-situ or using remote sensing approach (Mariotti, 2018; Mohammad et al., 2020). However, the in-situ approach should first establish a baseline data on a selected important location for example jetty area or future prospect development area. The distance of the channel width recorded and monitored over a period, as the changes within a channel will naturally take a long time it is advised to have a monthly of a first-year baseline data and after, continuously of yearly monitoring. By adapting a remote sensing approach, historical of over five years' channel geometry could be quantified using satellite images from a higher resolution imagery from Sentinel-2 which presumably appropriate for channel monitoring. For consistency, only images taken at a high tide are considered or, the delineation is based on the edge of mangrove trees. Those changes in channel width are calculated by the differences it made within the segments in a GIS software (Mariotti et al., 2018),

Mangrove Coverage

Mangrove coverage analysis can be analysed using satellite imagery by using various remote sensing techniques. One common method is to use spectral indices that are sensitive to mangrove vegetation, such as the Normalized Difference Vegetation Index (NDVI) or Enhanced Vegetation Index (EVI) (Pandey et al., 2019). These indices measure the difference in reflectance of near-infrared and red light, which is related to the amount of vegetation present in an area. In order to remotely define the mangrove area to the other, further method is to use supervised or unsupervised classification algorithms. Supervised classification involves selecting training samples of different land cover types and using them to train a classification algorithm. While the unsupervised classification involves clustering pixels in the imagery based on spectral similarity and then assigning land cover types based on the resulting clusters.

Mangrove Species

On the other hand, mangrove species analysis does have its impact on mangrove channel where their root system and type play an important role to hold sediment within a channel. The input parameters required for mangrove species, or its system determine its ability to accommodate or overcome the effect of the SLR to the minimum widening effect (Ellison, 2015). The

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identification of the mangrove species can be done through visual observation, using a field guide, or by collecting and identifying plant samples. Through the analysis one could determine the relative abundance of each species in the study area, as well as any patterns in species distribution or association. Further, the health status of them could also determine by measuring leaf chlorophyll content, soil nutrients, and salinity levels, but through visual observation the leaf colour could represent it by brown, yellow and green (Jiang et al., 2022).

Sea Level

Sea level and tidal range analysis within the mangrove channel in Malaysia can be analysed through sea-level records gathered from TLDM or JUPEM gauge stations and, additional data including rainfall data that could be gathered from the Malaysia Meteorological Department (Abdulkareem et al., 2018). Relative sea-level rise causes upward movement of the tidal range, introducing a range in the vulnerability of mangroves to relative sea-level rise will cause a greater relocation of intertidal habitats in microtidal areas relative to macrotidal areas. Assuming similar low net vertical accretion to clarify this point, a 1-meter SLR by 2100 will only cause a partial relocation of mangroves in a 4-meter tidal range area, but a total relocation in a 1-meter tidal range area. Hence horizontal relocation with 0.5 meters (from NAHRIM estimation) of relative sea-level rise would be very significant within Malaysia water. Successful mangrove ecosystem relocation requires not only habitat availability, but also mangrove sediment formation with suitable soil physio-chemical properties, and successful migration and establishment of ecosystem associates.

Bioturbation

Bioturbation analysis could be an indicator of the health of a mangrove forest because it is a process that is driven by the activities of organisms living in the sediments, which are an integral part of the mangrove ecosystem. In particular, bioturbation by burrowing animals, such as crabs, shrimp, and worms, can affect the physical and chemical properties of the sediment and the exchange of nutrients and gases between the sediment and the overlying water (Sarker et al., 2021). When a mangrove ecosystem is healthy, it typically has a high diversity and abundance of bioturbating organisms, which helps maintain the structure and functioning of the sediment ecosystem. For example, the burrows and fecal pellets of bioturbating animals can increase soil porosity and oxygenation, promote nutrient cycling, and enhance sediment stability, all of which can benefit mangrove growth and survival (Egawa et.al., 2021).

There are many ways to establish this parameter, however the nominated adaptation was narrowed down to two either the determination of crab abundance or the distribution of burrowed holes. The number of holes burrowed by organisms in the sampling area can be an important data point for assessing bioturbation activity. Burrowing organisms such as crabs, worms, and shrimp can create a network of burrows and tunnels in the sediment, which can have significant effects on sediment properties and nutrient cycling. By counting the number of burrows or holes in the sediment, researchers could estimate of the abundance and activity of burrowing organisms in the ecosystem (Egawa et al., 2021). However, it's important to note that the number of burrows alone may not provide a complete picture of bioturbation activity, as different types of burrowing organisms may create different types of burrows, and the size and shape of burrows may vary depending on sediment type and other environmental factors. Therefore, it's important to use a combination of data points, such as burrow size, shape, and density, as well as other factors like sediment texture and chemical properties, to fully understand bioturbation activity in the ecosystem. While the crab abundance was found to be

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related to the young mangrove age area where denser canopy with moisture sediment that influence the presents of the organism. The method implemented was usually pitfall trap however, it could be varied since they are motile and move freely (Siti-Aminah et al., 2020).

Boating Frequency
Boating frequency analysis does have an impact on mangrove channels directly. High levels of boat traffic can cause erosion and sediment disturbance, which can negatively affect mangrove channels and their associated ecosystems (Ibrahim et al., 2019). In addition, boat propellers can damage the roots of mangroves, which can lead to loss of vegetation and channel instability. Moreover, boat traffic can also lead to an increase in pollution, which can further harm mangroves and the surrounding ecosystem (Fauzi et al., 2017). It is therefore important to consider the impact of boating frequency in the assessment of mangrove channel vulnerability, and to take measures to mitigate negative impacts, such as by limiting boat traffic or implementing guidelines for responsible boating in mangrove areas.

Stakeholder Adaptive
The stakeholders and community involvement (including agencies, authorities, NGOs, industries, local community etc.) suggested should only focused on mangrove conservation measures carried out within the channel areas such as mangrove replanting, wake reduction, and any action proven to reduce the impact on the area (Ellison, 2015). This data will complementarily strengthen the channel structure support and assisting to counter the exposure and sensitivity in the assessment later. As an opposition to the impact, adaptive works will impose significant impact based on the effectivity and reliability on its implementation. The identification of these inputs will help in considering the adaptive capacity of the channel because by using mangrove channel approach banks area, mangrove roots system, and water wake are important factors.

Vulnerability Analysis
Deriving from previous studies, the assessment of each parameter is suggested to go through a series of assessment (Figure 8) which started by; determine the best parameters that will give an appropriate representation of the mangrove channel into their appropriate components (as discussed), then all parameters will be ranked into 5 scales of scores categories using natural break classification method from their recorded minimum and maximum data; for their contribution to each component's. Considering equation (1) into formulation of net VI, the semi-quantitative scores for EI and SI according to scale 1-5 scale; 1 indicates a low contribution to vulnerability, while 5 indicates a high contribution, however for ACI the scale is vice versa where 1 indicates good adaptive measures while 5 indicates none or no action for mitigation. Finally, the overall score for vulnerability will be produce by averaging the total score according to completed parameters as in equation (2). In order to conclude the application of the index a subtle action for future adaptation will be recommended.

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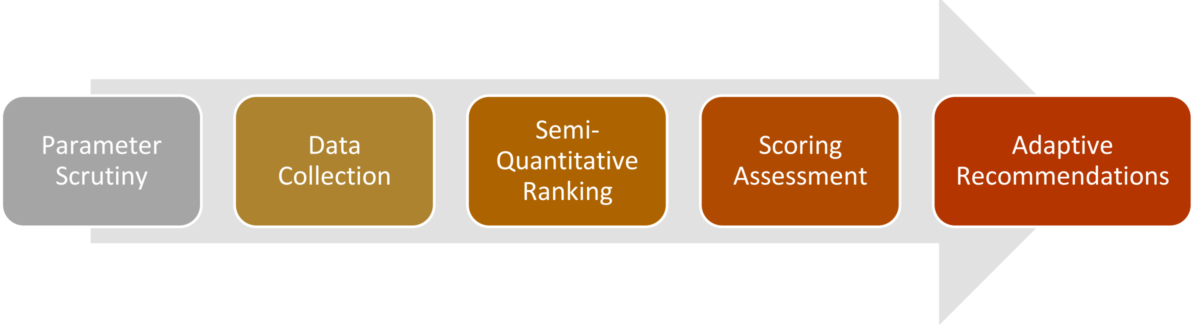

Figure 8: The Workflow Of The Mangrove Channel Vulnerability Assessment Concept.

Conclusion

Above all, various studies on a large scale have been conducted to assess the effects of mangrove vulnerability with multiple categories approach. Most of them focus only on coastal areas using remote sensing and are related to coastal assessments. However, there is a gap that needs to be studied upon, the channel with tidal effect from within the mangrove area. It is recognized that these channels are important nurseries area for marine fisheries and biodiversity, as any damages to them, will be a weak point impacting the mangrove and certainly affecting marine resources. The concept proposed to represent the vulnerability index is utilizing the vulnerability scoping diagram (VSD). The most sensitivity component that are paid less concern is channel widening for changes in the channel morphology which connected sediment erosion within the area.

The analyses suggested considering the use of satellite imagery which is a cost-effective and efficient way to monitor changes in mangrove ecosystems over time and can provide valuable information for management and conservation efforts. On the other hand, some in-situ observations which are accessible to all were also suggested for ground description about the area of interest. The interpretation of post-assessment with consideration of relevant ecological, geological, and anthropogenic factors that may affect the mangrove channel will contribute to the current status of the mangrove area. The survival and coverage of mangrove near to the channel area depends on their species adaptability and human action towards it as many findings pointing for awareness and reviving the environment.

In line with these, this study is expected to contribute to the good impact and strengthening of planning sustainable development such as identifying future threats that outline in environmentally sensitive areas (KSAS) especially in Physical Development Planning of Islands and Marine areas. As the aspiration within the Shared Prosperity Vision 2030 (SPV2030); the relevant parties should plan to create a resilient economy, where researchers should play their role to supports sustainable ecotourism, green tourism, and sustainable agriculture. The mangrove forest is one important ecosystem service with many coastal communities across the tropics that provision as fishing grounds and nursery areas (SDG14). Besides, Mangroves provide additional services to coastal communities, including storm protection, pollutant trapping, and a variety of cultural ecosystem services, including their role in carbon sequestration and storage. Any changes to preserve and conserve will be beneficial to combat and reduce the climatic impact within the region (SDG13). This is important for islanders such as Langkawi in trying to achieve sustainable cities and communities (SDG11).

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